# Study of Charmonia Production vs. Charged Track Multiplicity in p+p Collisions at PHENIX

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for PHENIX Collaboration

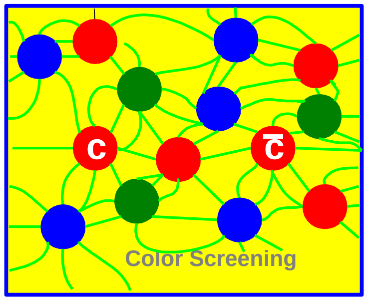
# Outline

- Motivation
- $J/\psi$ and $\psi'$ relative $R_{d+Au}$ at PHENIX
- Forward Vertex detector (FVTX) upgrade of PHENIX experiment in RHIC
- $J/\psi$ and $\psi'$ separation in p+p using FVTX
- Charged track multiplicity analysis using FVTX
  - **New observable in PHENIX**
  - under going

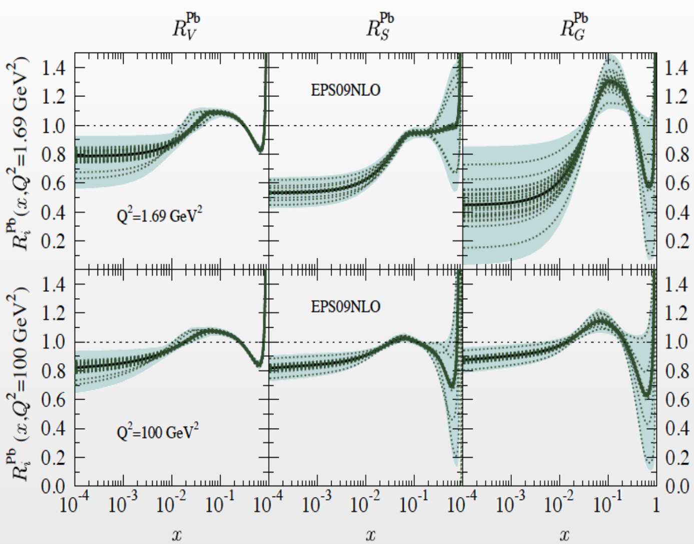
# Motivation

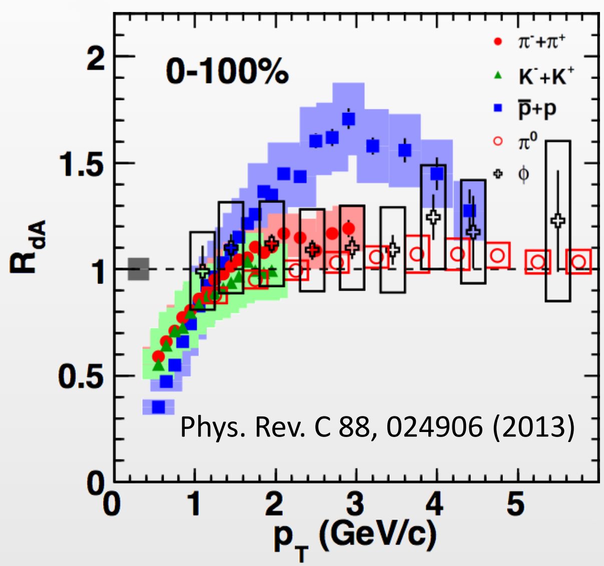
- Study quarkonia suppression mechanism
- Many competing effects:
  - Parton shadowing
  - CNM Initial and final state effects
  - QGP color screening effects
  - Regenerations etc.
- Study quarkonia suppression in smaller systems like p+p could provide new information

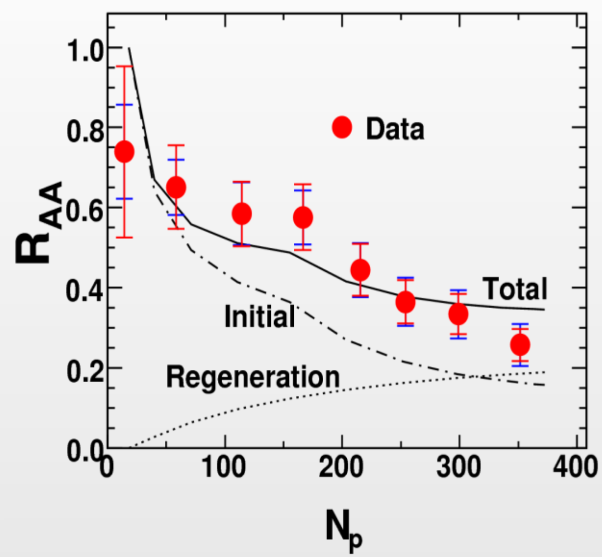
QGP color screening



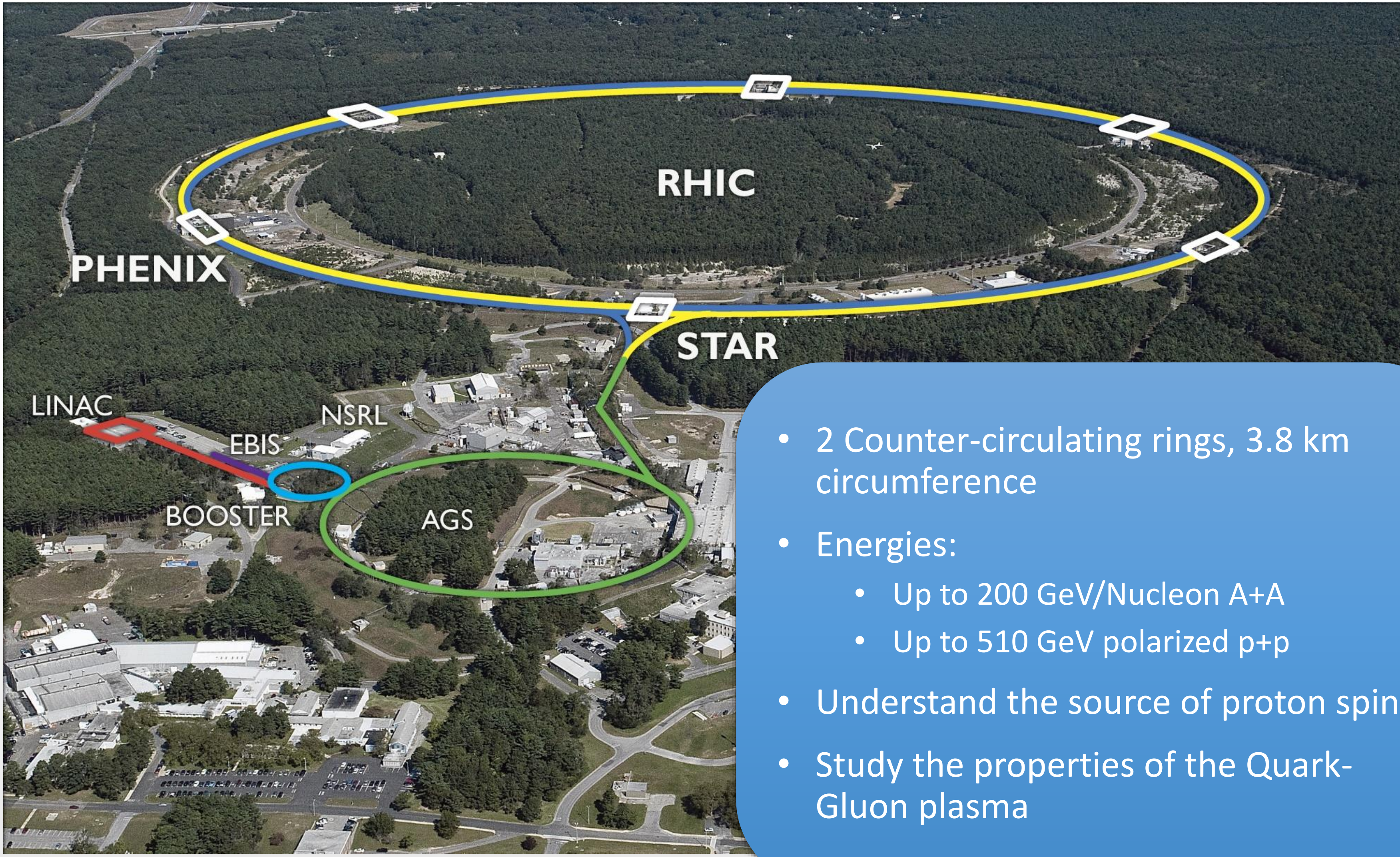

J/$\psi$ suppression and re-generation at RHIC



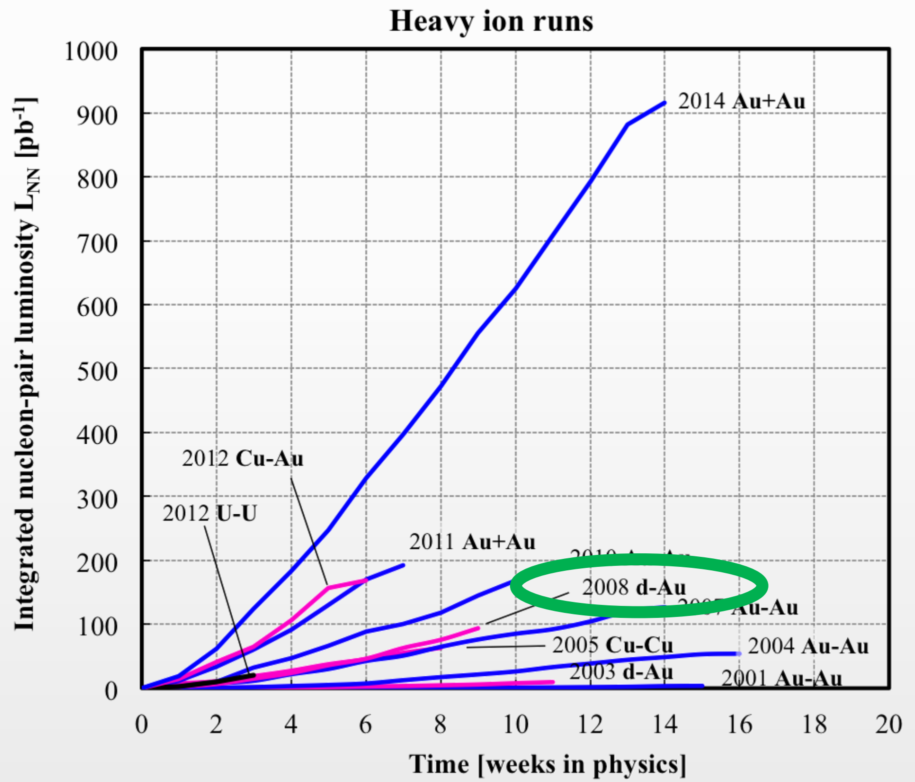
# RHIC

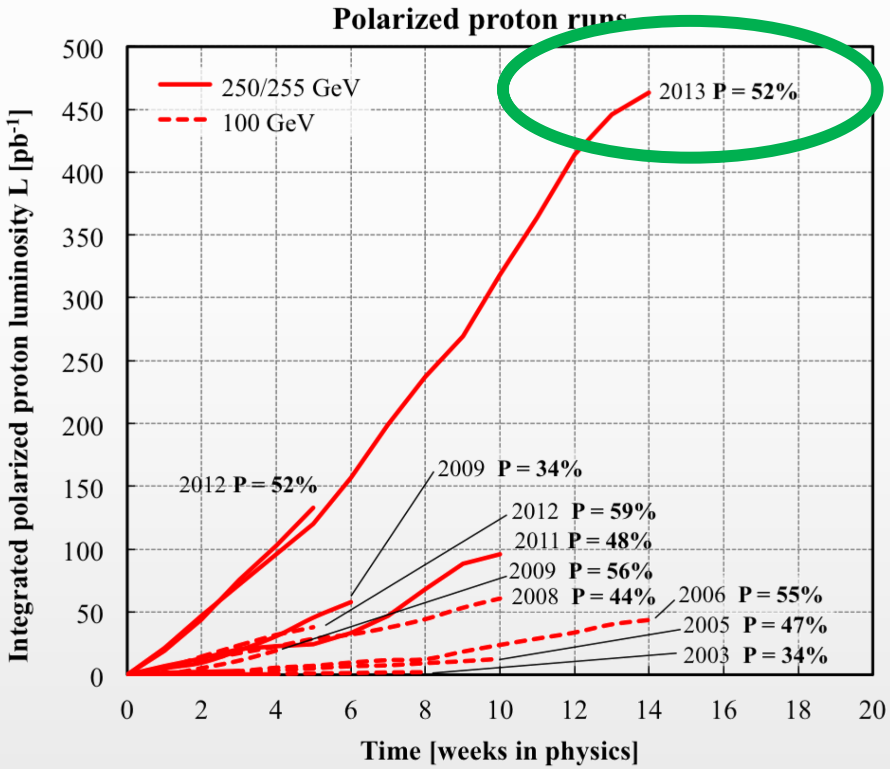



- 2 Counter-circulating rings, 3.8 km circumference
- Energies:
  - Up to 200 GeV/Nucleon A+A
  - Up to 510 GeV polarized p+p
- Understand the source of proton spin
- Study the properties of the Quark-Gluon plasma

# Data sets used in this talk

- 2008 run d+Au @ 200 GeV
- 2013 run p+p @ 510 GeV



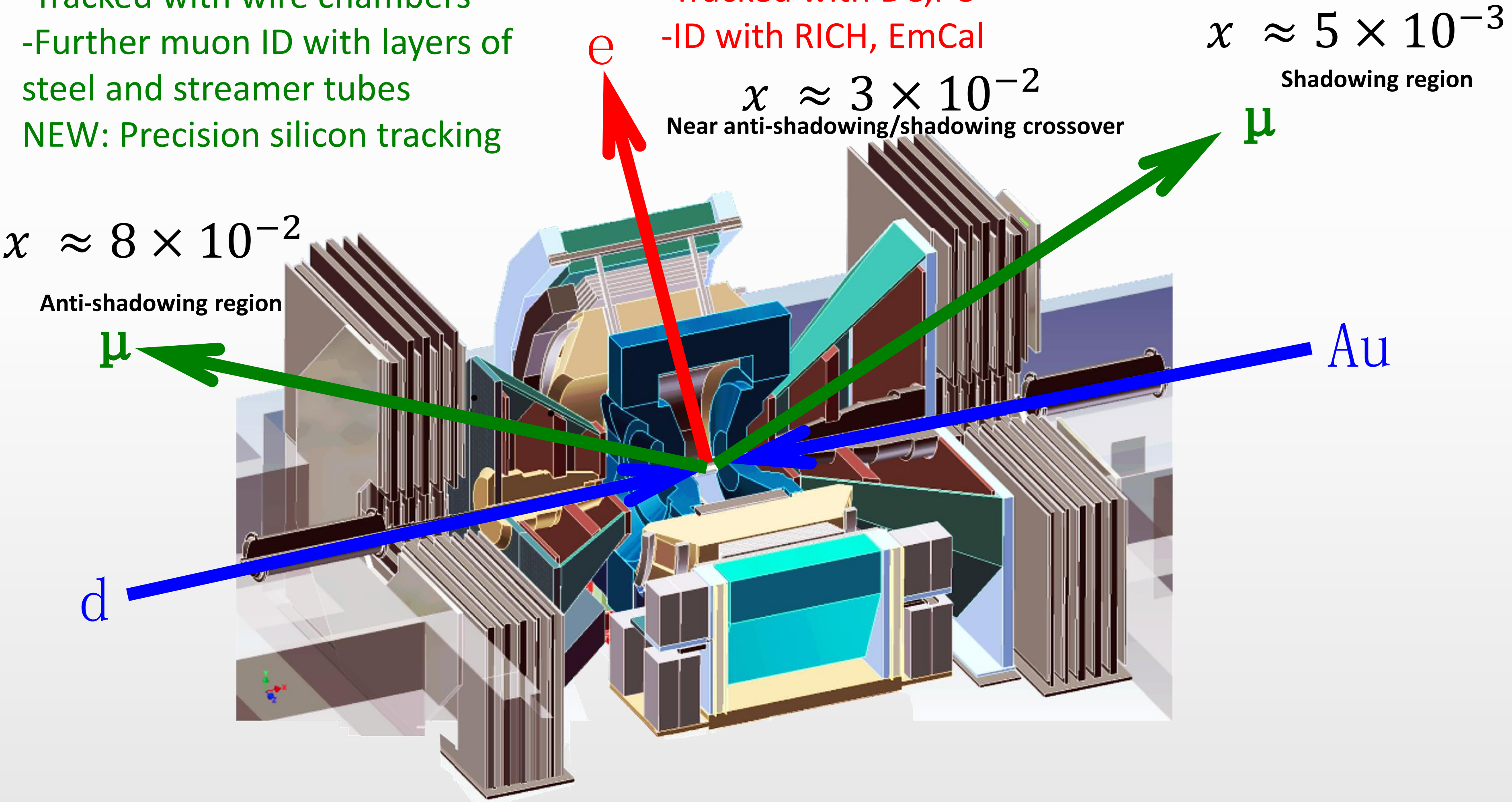



# Quarkonia at PHENIX in d+Au collisions

Designed to measure quarkonia down to pT = 0 through di-lepton decays at mid and forward rapidity:

Muons: 1.2 < |y| < 2.4,
-Tracked with wire chambers
-Further muon ID with layers of steel and streamer tubes
NEW: Precision silicon tracking

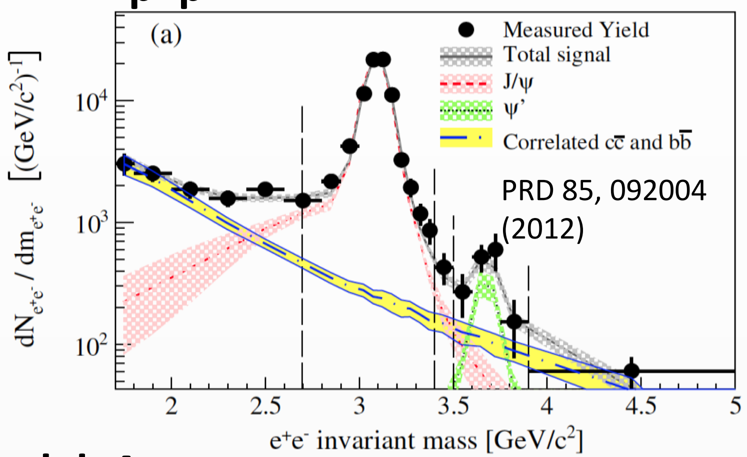
Electrons: |y| <0.35,
-Tracked with DC,PC
-ID with RICH, EmCal



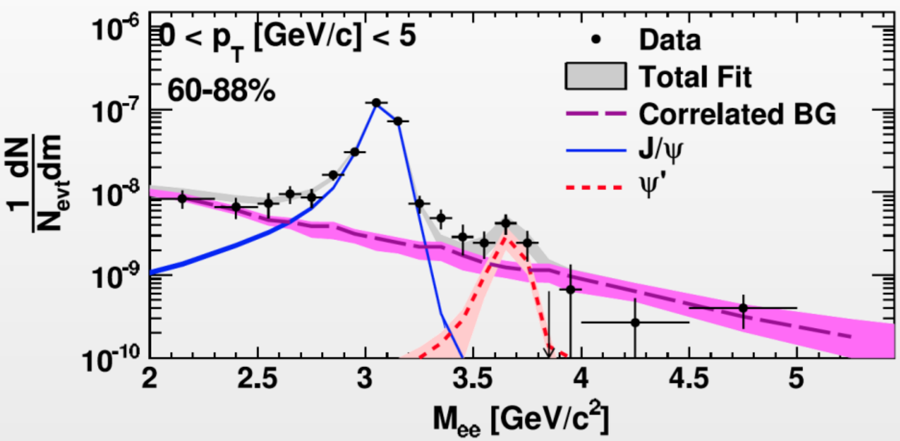
# Charmonia production in d+Au in PHENIX Central Arm

- PHENIX ee measurements at midrapidity in p+p:
  - $\psi(2s)/\psi(1s) = 2.1 \pm 0.5$ %
- $\psi(2s)$ is *very* weakly bound: $E_b$ ~50 MeV
- Finalized measurement in d+Au:
  - PRL 111, 202301 (2013)

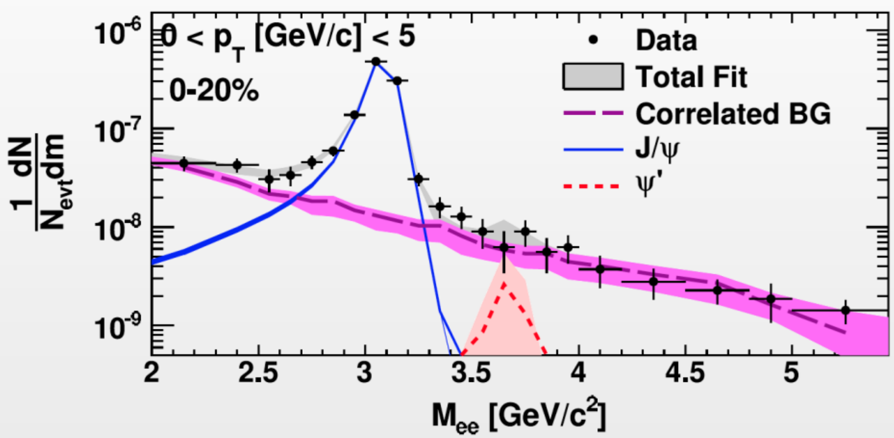
**p+p**




**Peripheral d+Au**



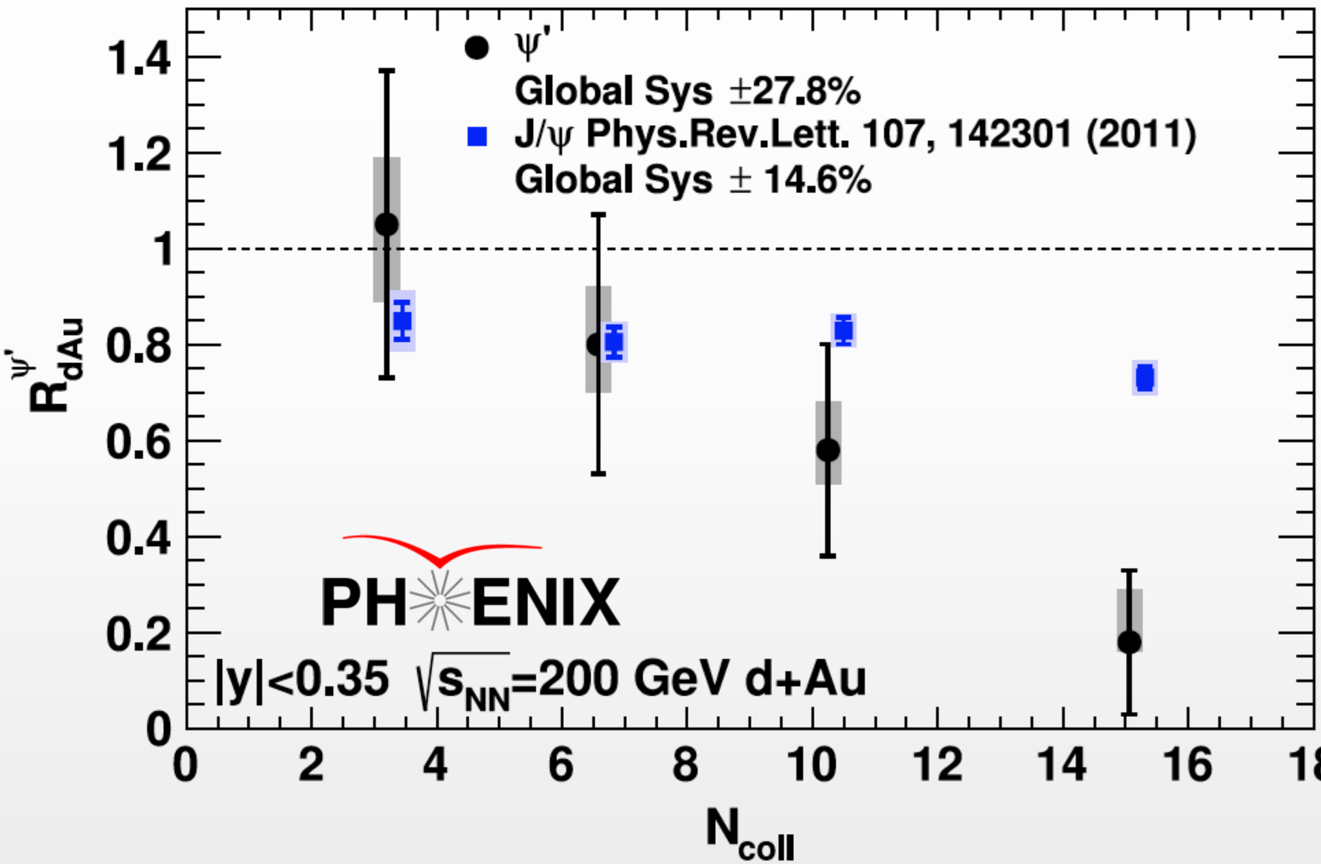

**Central d+Au**




By eye, clear difference in peaks between peripheral and central d+Au

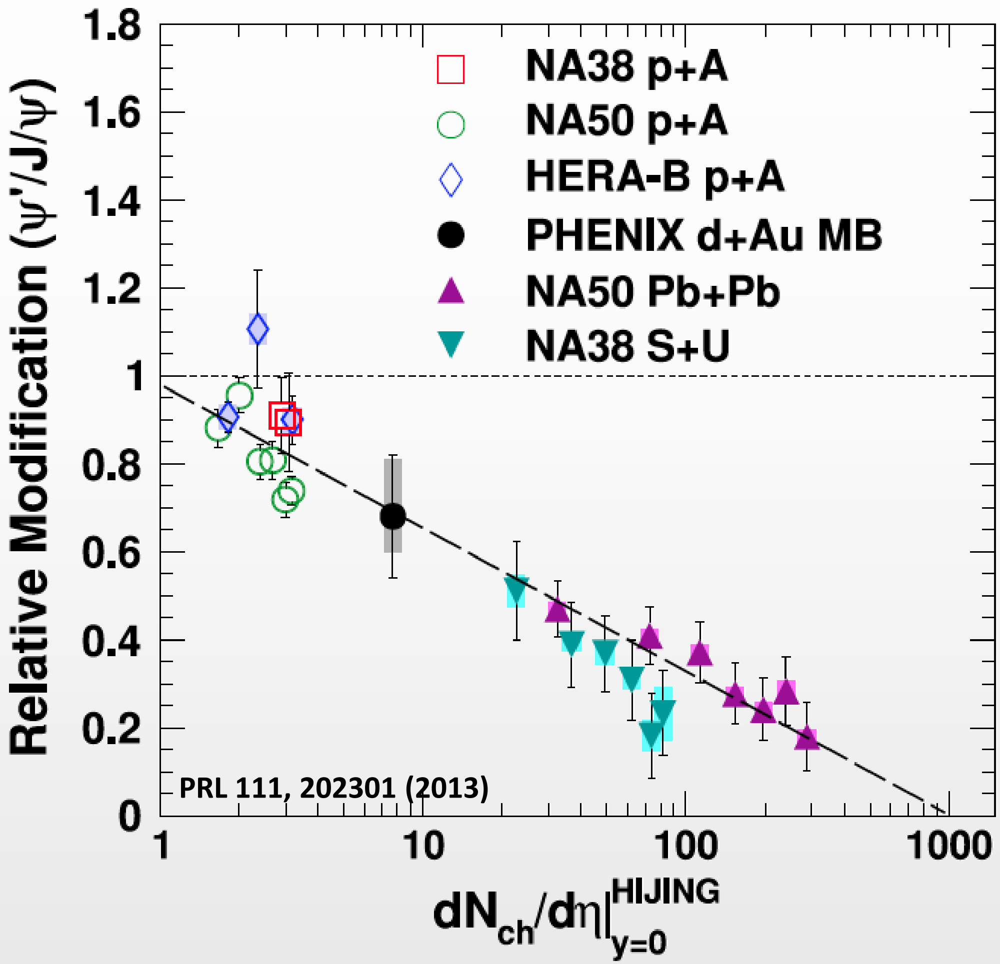
# Nuclear Modification $R_{dA}$

PRL 111, 202301 (2013)




$\psi$(2s) more suppressed by a factor of ~3 in central collisions
Very different trend than $\psi$(1s)

# Relative Modification of $\psi(2s)/\psi(1s)$ – particle density @Central rapidity



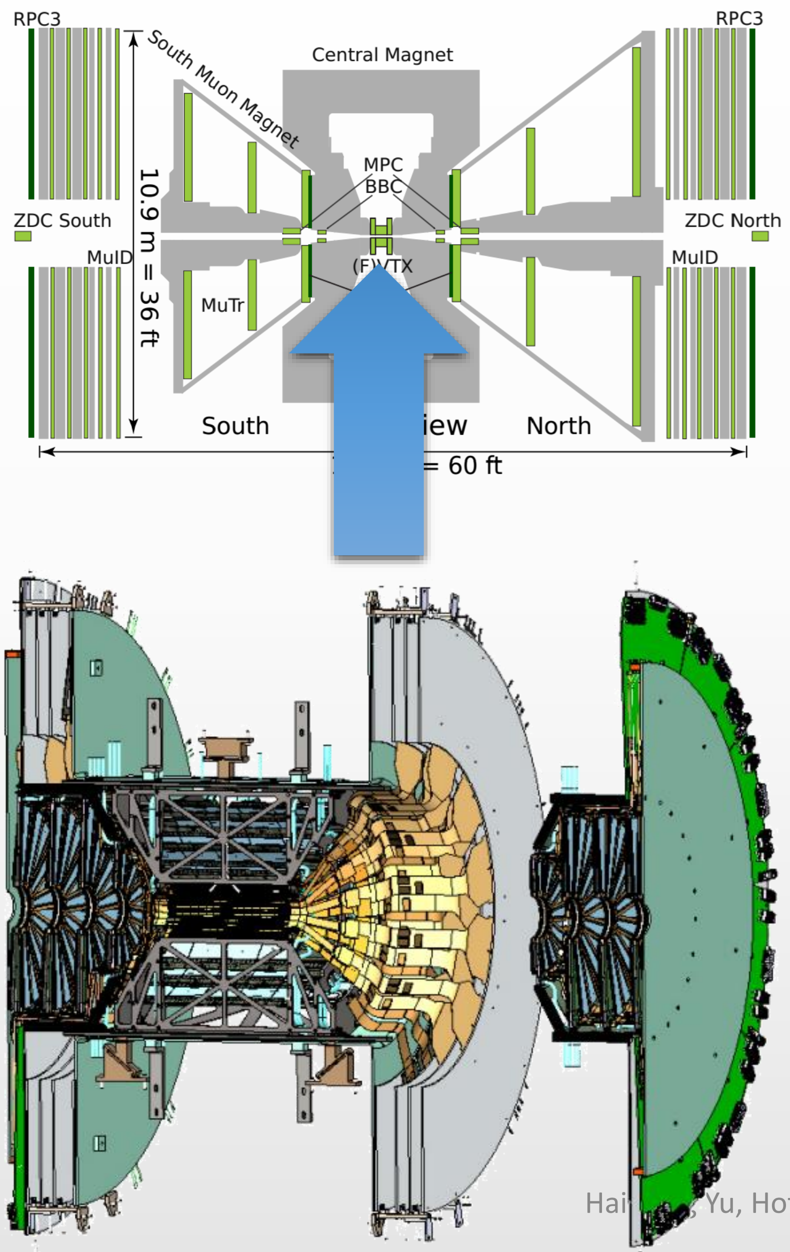

- Relative modification in *all* systems follows common trend with increasing produced particle density.
- Co-mover (or medium?) density seems to be the relevant quantity. (*Phys. Lett. B 393, 431 (1997)*).
- Study charmonia suppression in smaller systems (p+p) could help to clarify this

# To do this relative charmonia suppression vs. multiplicity measurement in muon arm:

- $\psi$(2s)/$\psi$(1s) separation
  - better inv. mass resolution

- multiplicity determination
  - charged track number measurement
  - need to handle pile-ups in high luminosity runs (like RHIC 2013 p+p run)

# Forward Silicon Vertex detector upgrade of PHENIX




PHENIX Muon Arm:

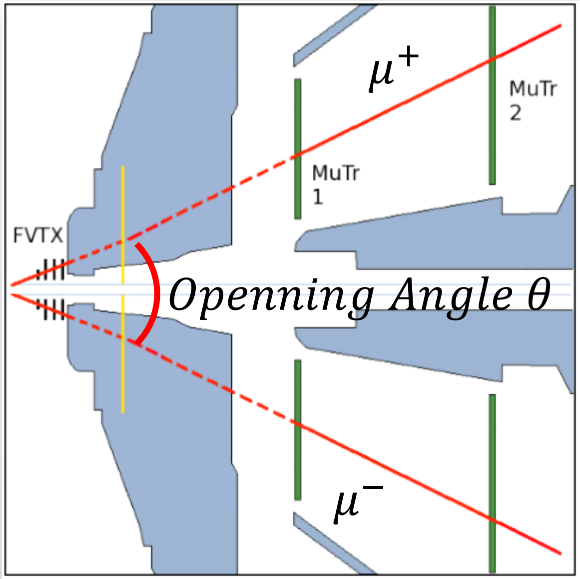
- Momentum measured in cathode strip tracking chambers (MuTr)
- Muon ID from Iarocci tubes interleaved with steal absorbers (MuID)
- $1.2 < |\eta| < 2.4, \quad \Delta\phi = 2\pi$

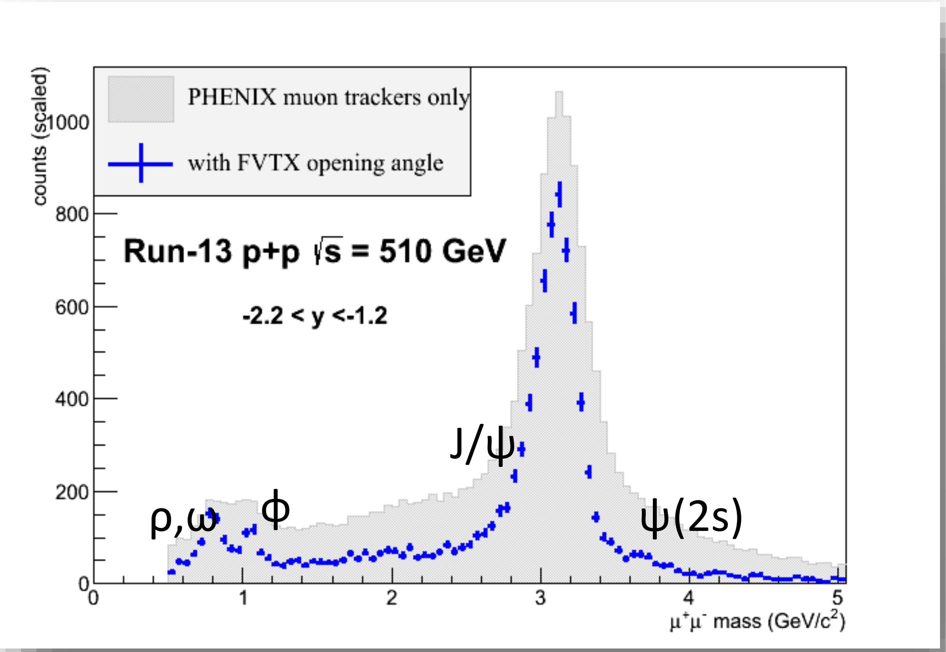
FVTX detector:

- $1.2 < |\eta| < 2.4 @ Z = 0cm$
- Expected distance of closest approach (DCA) resolution is 200 $\mu m$ for tracks with pT ~ 5GeV/c
- ~ 1M channels

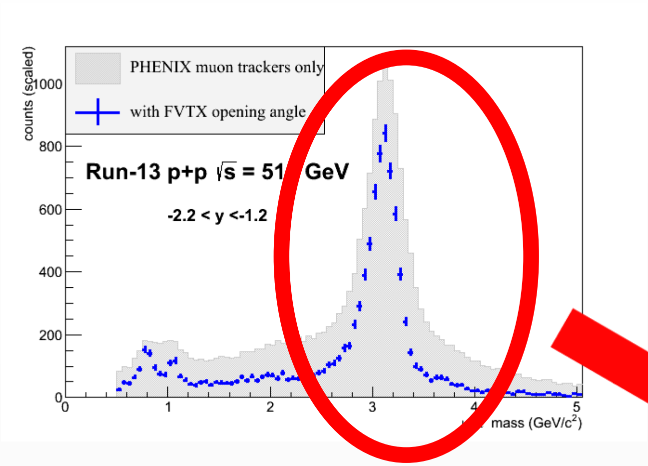
# J/$\psi$ and $\psi'$ Separation with FVTX

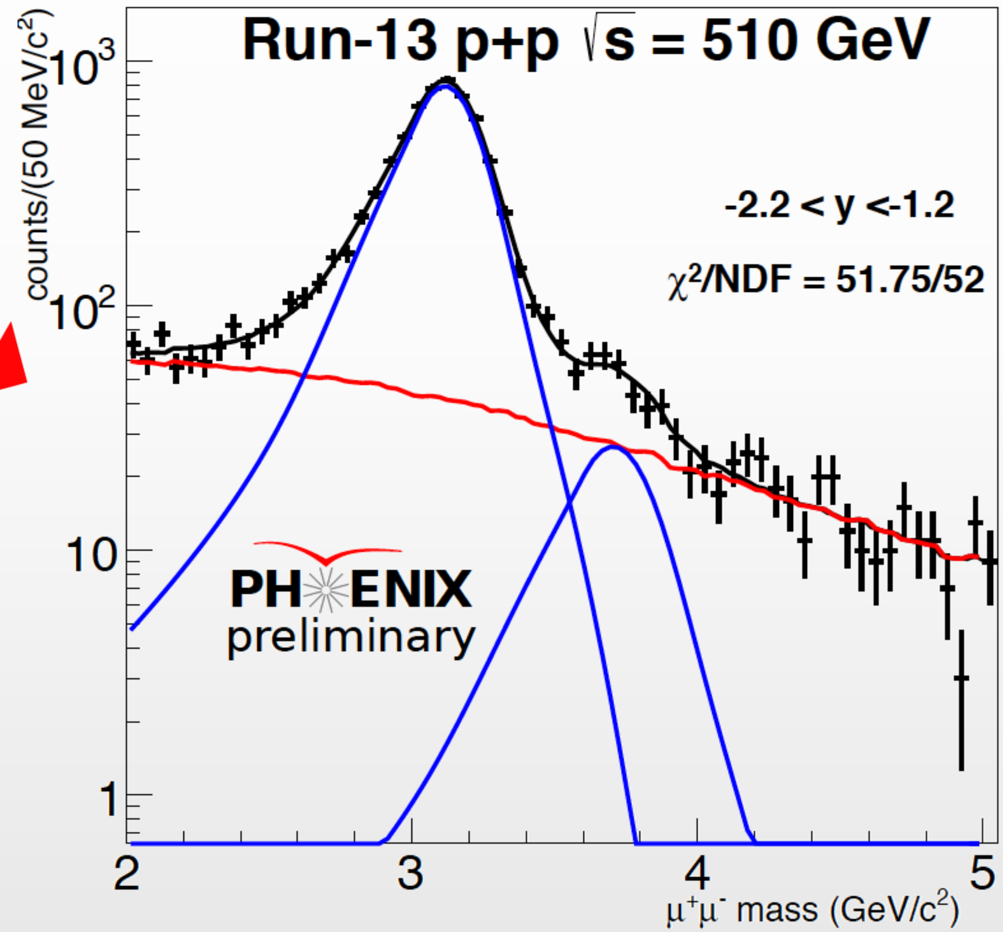
Muon tracks get smeared inside the absorber. FVTX helps to do much improved opening angle measurements



# Extracting the $\psi$(2s) peak

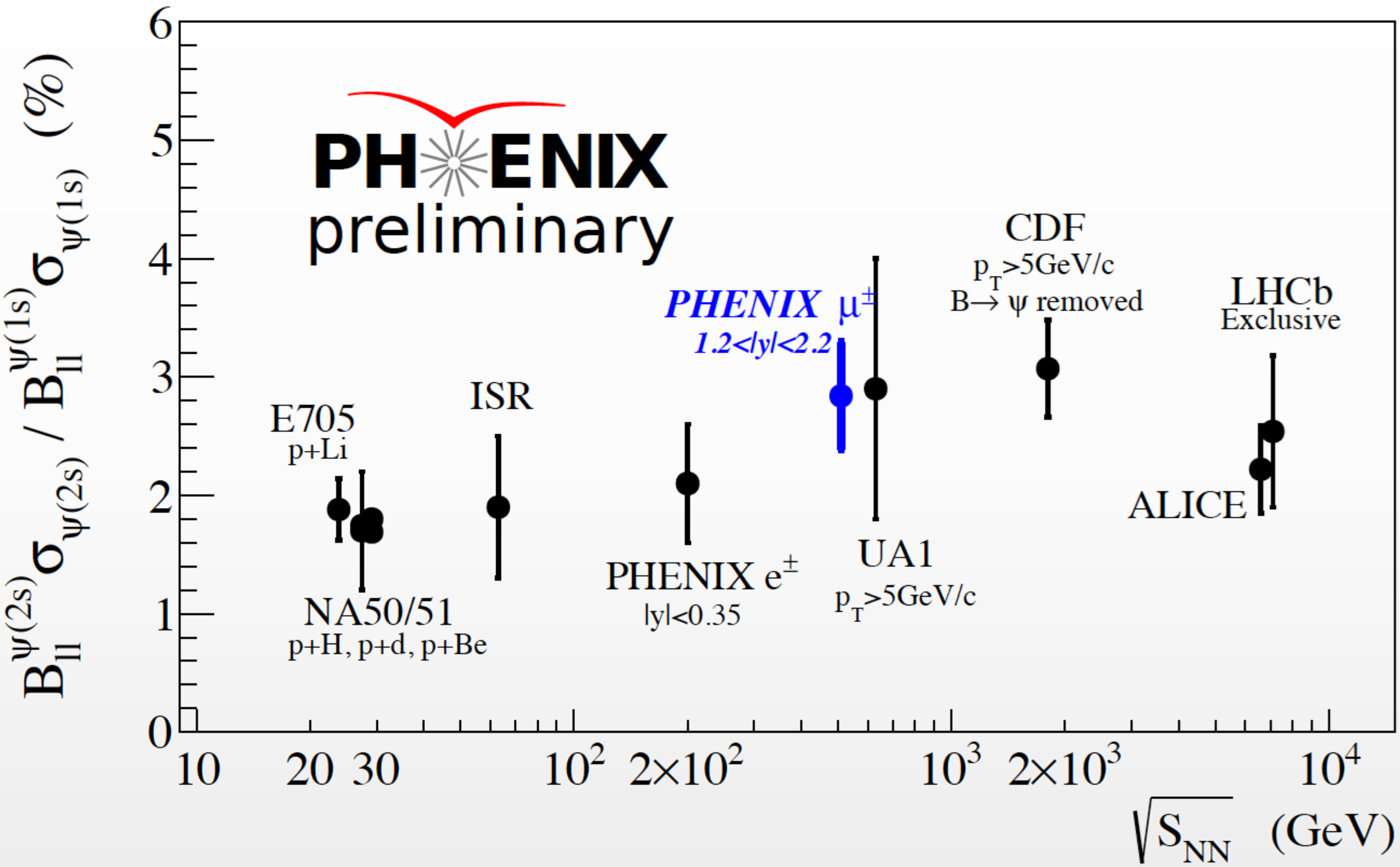



Signal peaks:
Crystal Ball + Gaussian

Background:
mixed event combinatorial + exponential continuum

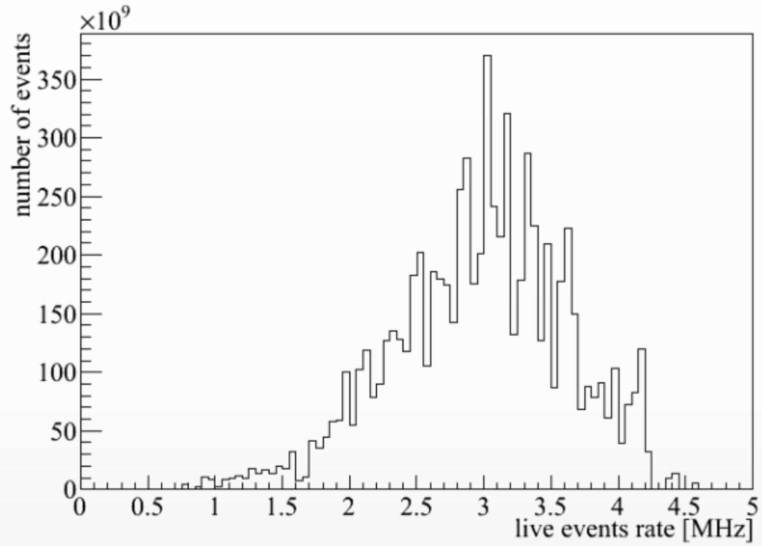
# $\psi(2s),\psi(1s)$ ratios vs. $\sqrt{s}$



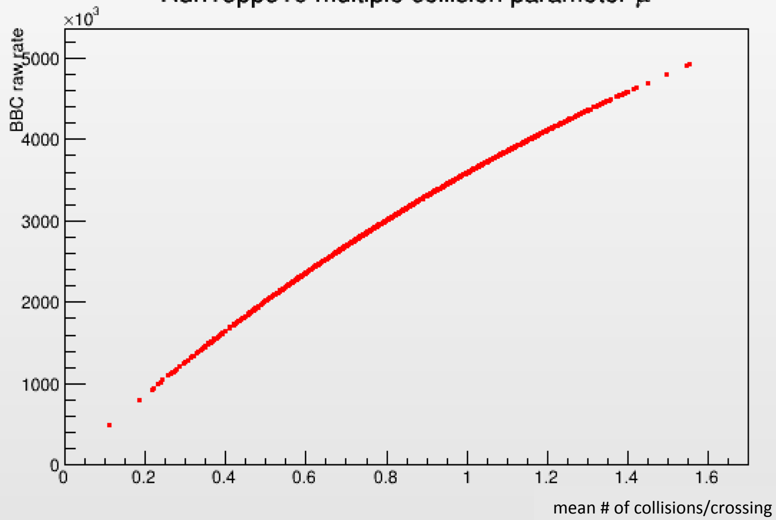

First measurement at 510 GeV. First measurement at forward rapidity at RHIC.
Consistent with world data.
➔p+p baseline well understood experimentally.

# Charged Multiplicity Analysis using FVTX

Multiple collisions per crossing in RHIC 2013 run

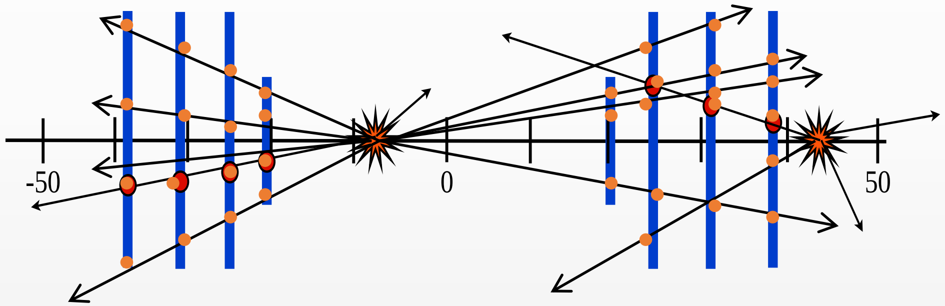



Run13pp510 multiple collision parameter μ

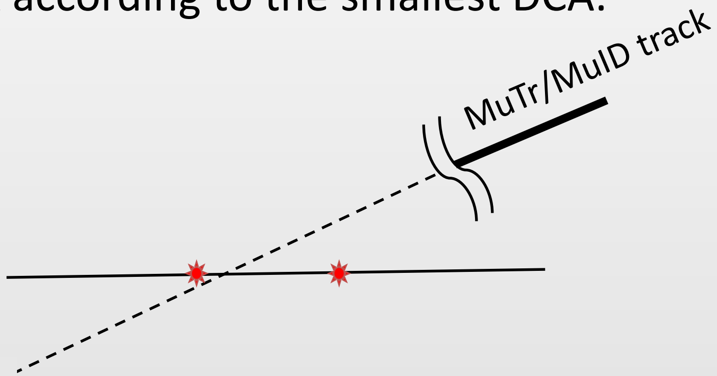



To handle this multiple collision, we do 2 associations:

Each FVTX tracklet is associated to a vertex according to the smallest DCA.

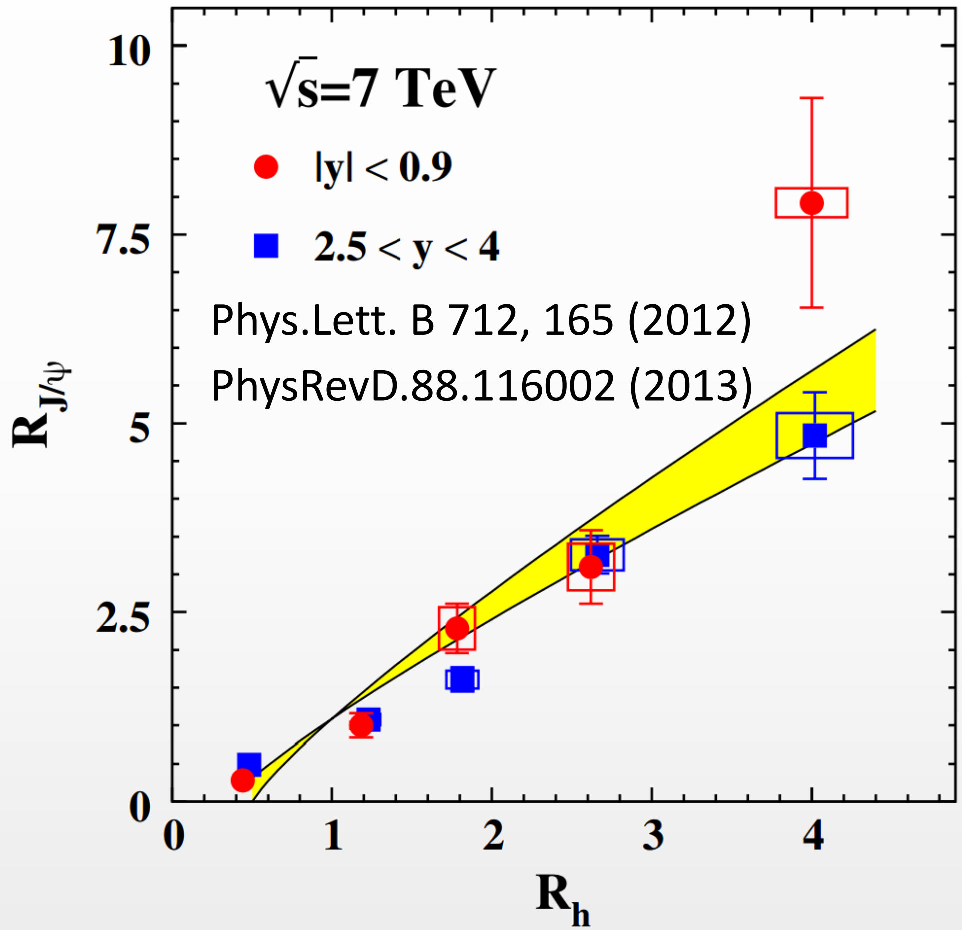



Each Mutr/MuID track is also associated to a vertex according to the smallest DCA.



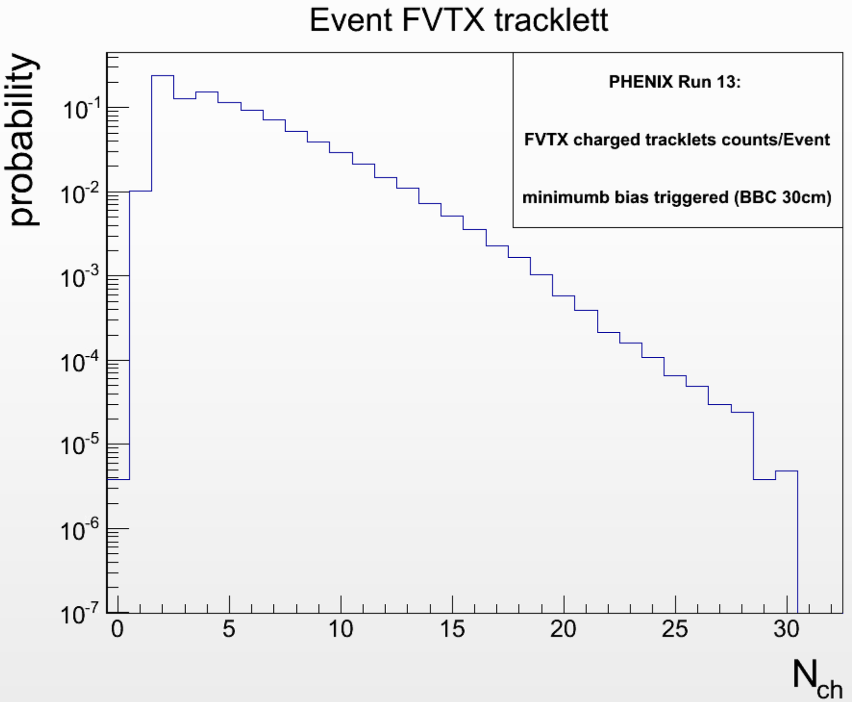
# J/ψ production enhancement in high multiplicity event compared with minimum bias event:

- In LHC 7 TeV p+p collision, a near linear relation was found between the normalized J/ψ production rate and normalized multiplicity
- Based on the multiple parton interaction explanation, by comparing the pA collision scenario, B. Kopeliovich etc. set up a simple model which produces nice consistency with the data.
- So we want to see If this would be the same thing at RHIC energy.

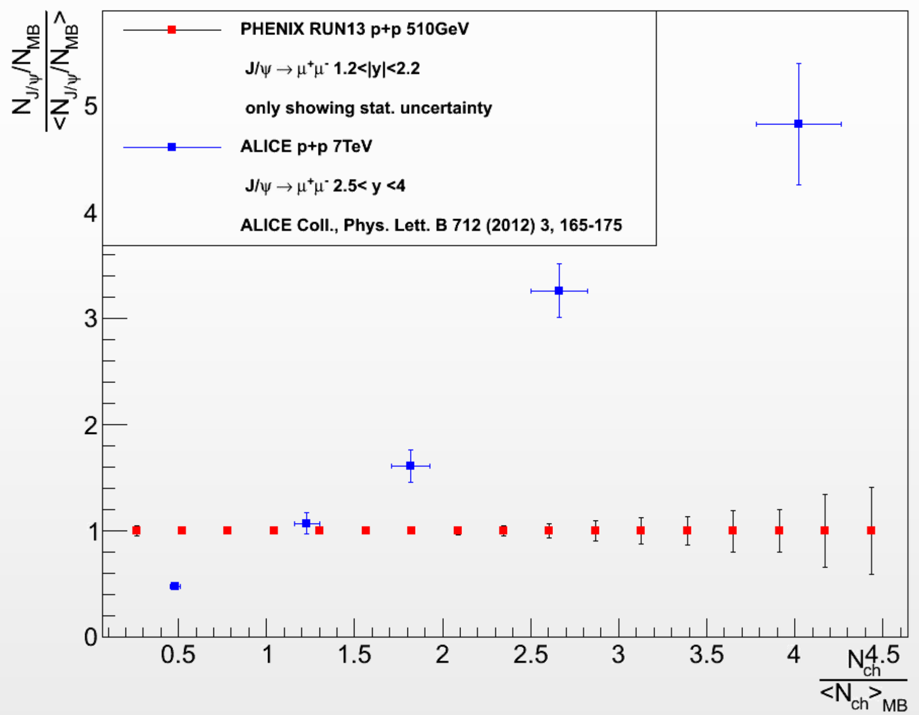


# Charged multiplicity distributions in p+p 510GeV (Run13) and the stat. err. projection

charged track multiplicity per crossing




Normalized J/ψ yield vs. normalized multiplicity: projection of the stat. err.



# Summary

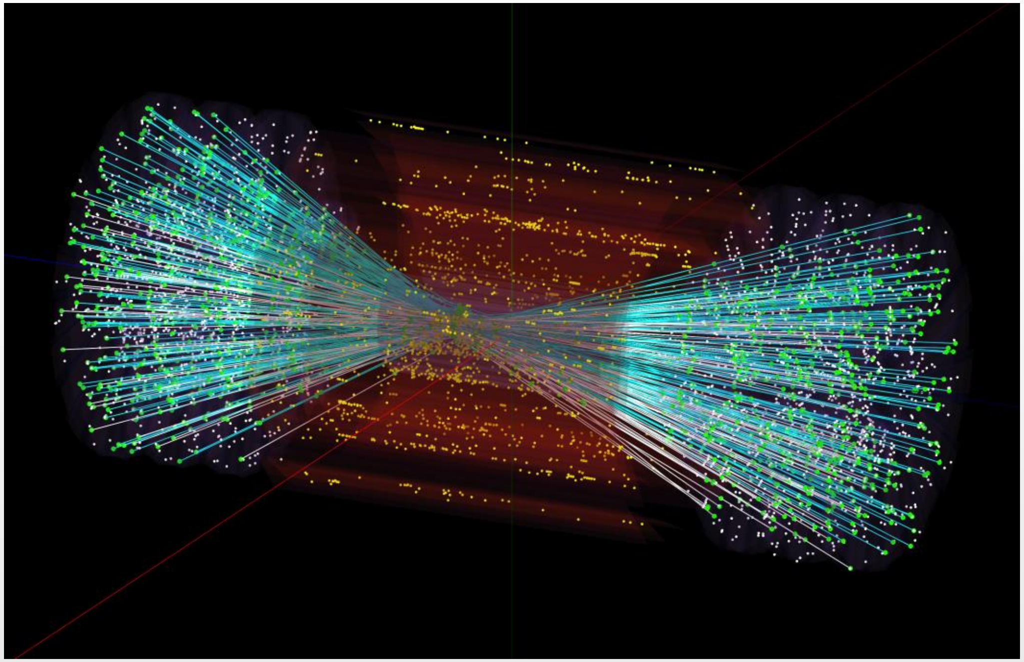
- With the newly upgraded FVTX detector in PHENIX, we are able to
  - do multiple vertexing
  - measure better μ tracks opening angle
  - directly measure charged track multiplicity
- Study charmonia production in p+p collisions in event with different multiplicities could contribute to further understanding the quakonia breakup mechanism
  - Have J/ψ and ψ' separation result
  - Track multiplicity analysis going on
- J/ψ yield vs. charged multiplicity
  - Straightforward with the track multiplicity analysis
  - Could give $\sqrt{s}$ dependence for comparison

# Backups

# Near Future Plans (Run14, 15)

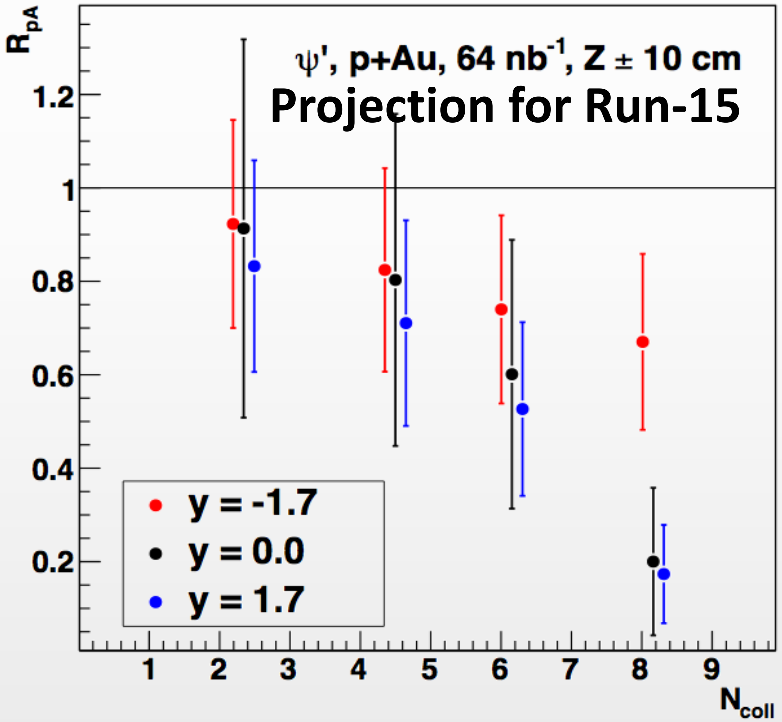
**Run-14: 200 GeV Au+Au:**

**Our BEST Au+Au dataset ever.**
**First Au+Au with FVTX.**



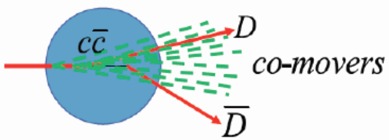
Reconstructed FVTX tracks in a typical Au+Au event

**Run-15: 200 GeV p+Au**
**First p+Au at RHIC**

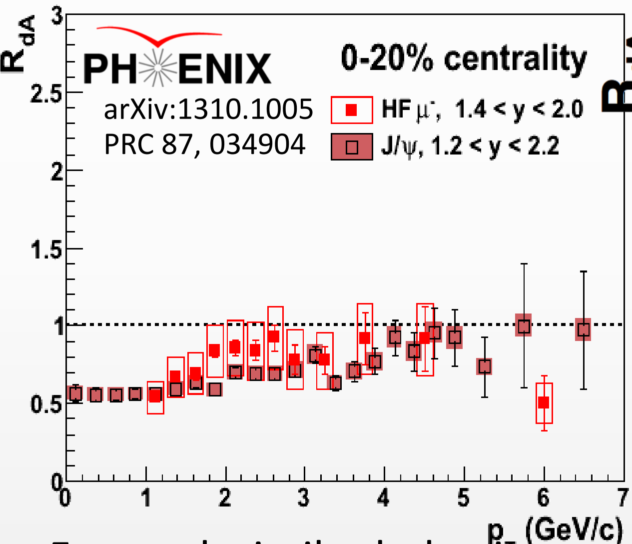


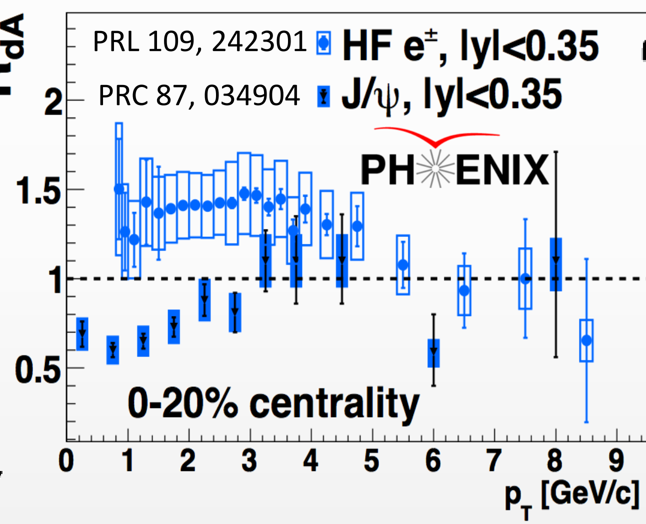
# Open HF versus J/$\psi$

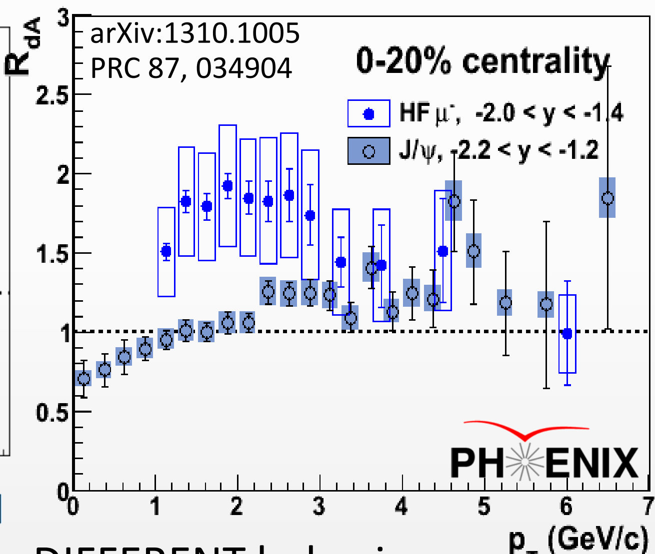
Sensitive to same initial state effects: gluon shadowing, kT broadening, partonic energy loss in nucleus
BIG difference: nuclear breakup of charmonia bound states




*Keep in mind different kinematics for decay leptons from single charm quark versus fully reconstructed *cc* state



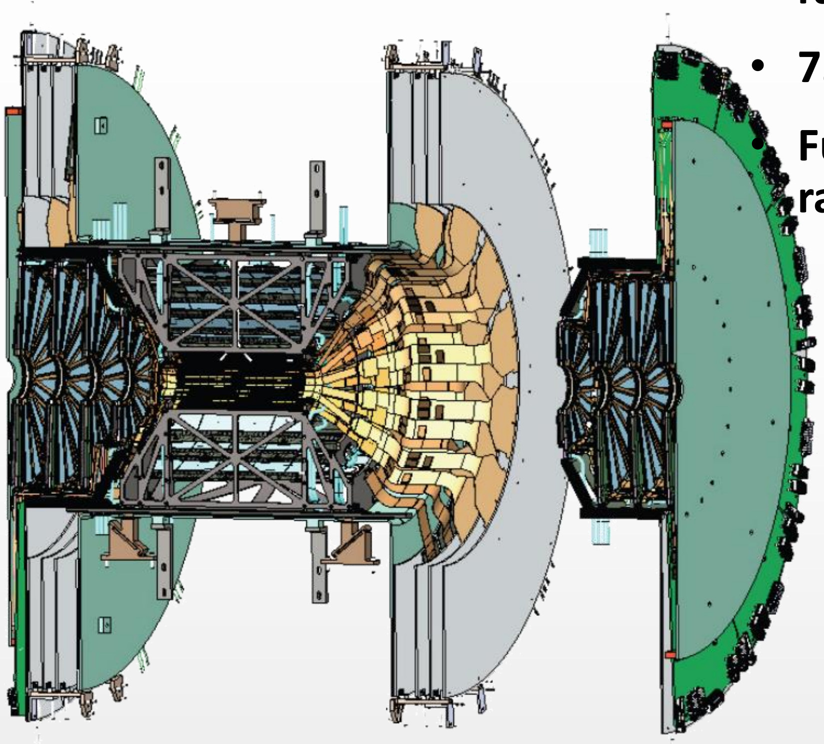

Forward: similar behavior
-Short time in nucleus
-Low co-mover density

Mid- and backwards rapidity: DIFFERENT behavior
enhanced open HF versus suppressed J/$\psi$

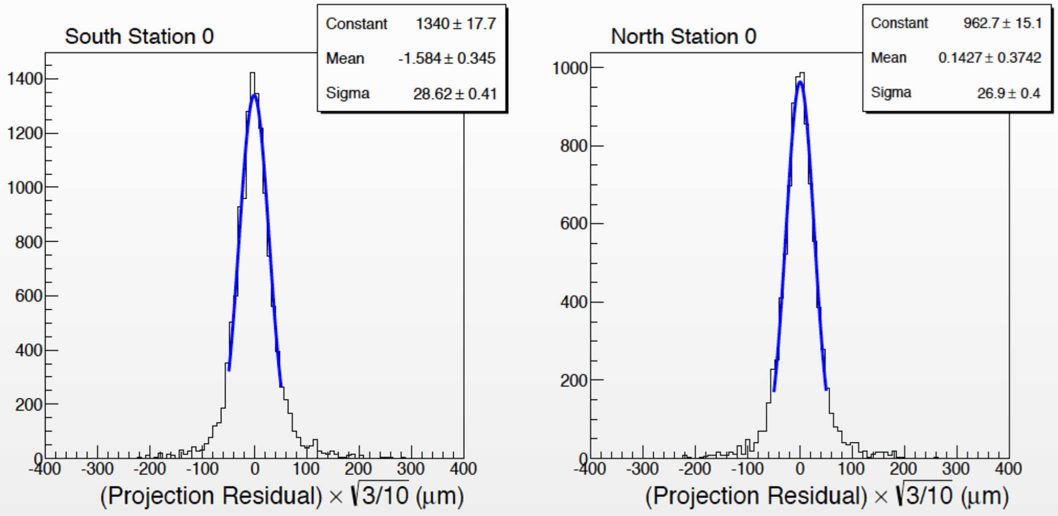
## Compelling evidence for significant *cc* breakup effects

# Precision Tracking at Forward Rapidity: the FVTX

**Forward Silicon Vertex Tracker**



- **Four layers of silicon sensors in each end of central rapidity silicon**
- **75um pitch in r, 3.75 deg in phi**
- **Full azimuthal coverage at forward and backward rapidity**




**Details just published: NIM A 755 (2014) 44**

- **Position resolution better than 30 um in each station**
- **Single hit efficiency >95%**

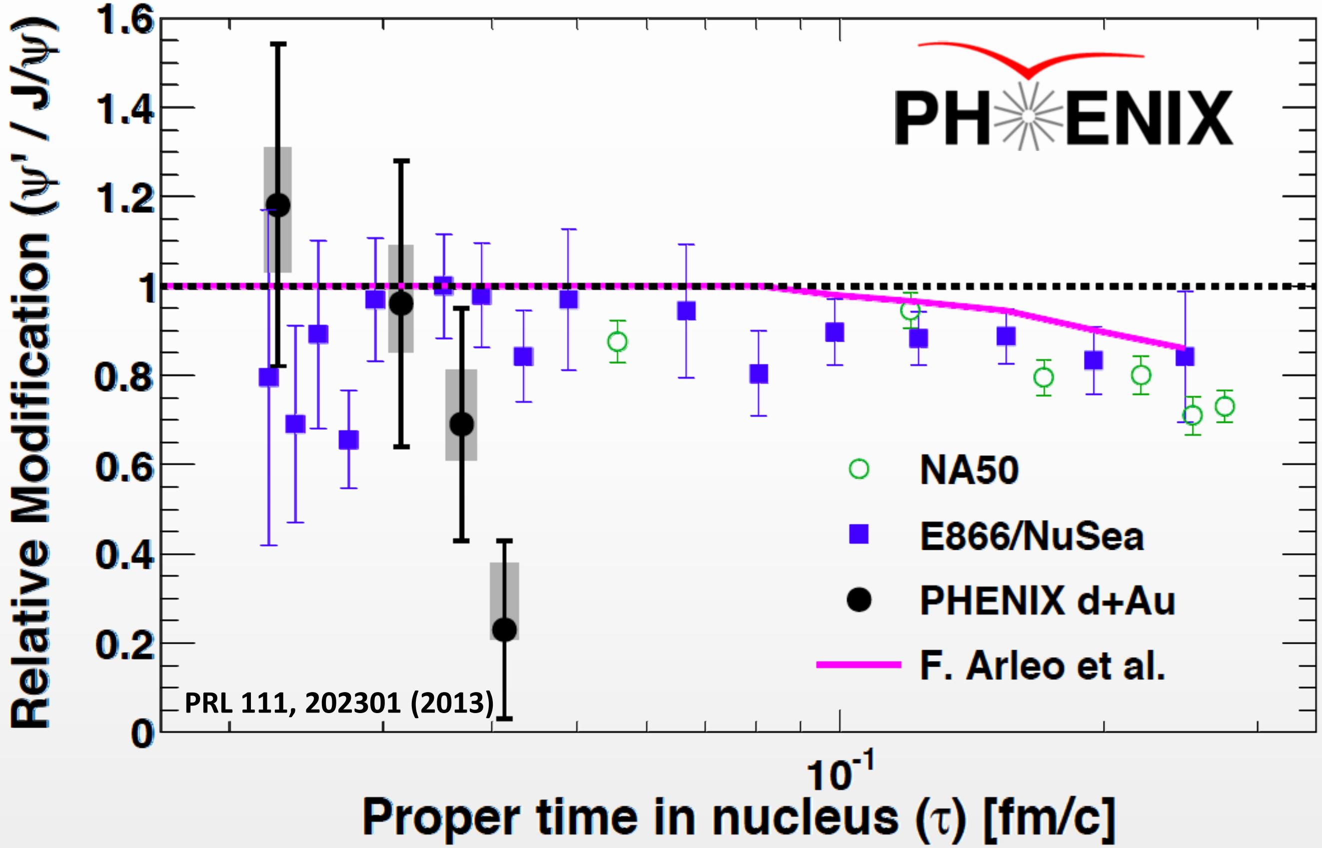
# Relative Modification of $\psi(2s)/\psi(1s)$ – time in nucleus

After *cc* formation, the pair expands as it crosses nucleus

$\psi(1s)$ formation time ~0.15 fm

At RHIC, τ ~ 0.05 fm

Precursor state crosses nucleus before final state meson forms




Increased suppression NOT due to same breakup mechanism while inside nucleus.
Breakup *outside* nucleus (co-mover interactions)?
Or is there an altogether *different* mechanism at RHIC energies?